Systematic Approach to Develop an Optimized Nozzle Design for Up to Date and Future Demands

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Schottel
DUCTED PROPELLER

SYSTEMATIC APPROACH TO DEVELOP AN OPTIMIZED NOZZLE DESIGN FOR UP TO DATE AND FUTURE DEMANDS

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   Optimization Technique / Approach
   Market Study / Predesign
   Parameterization
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   Model Tests

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01 Introduction

>> Background

Principal use:

Nozzle used to increase thrust at low speed operation

Performance:

highly dependant on nozzle profile
New development, design objective:

**High-Speed Optimized Nozzle**

- **Main Operating Speed:** >10 kn
- **Goal:**
  - Efficient @ higher Speeds
  - High DP-Thrust

**Compromise Design**

New Development
Requirements for the new compromise duct:

- suitable for a wide range of various applications
- identical bollard pull as standard nozzle WAG19A-mod
- improved free running performance (fuel economy)
- minimized space for installation

...which nozzle design???
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02 Nozzle Optimization
>> Optimization Technique

**Optimization Technique**

**Traditional:**
Modeltest, Experiments

**Virtual Product Development:**
Computer Simulations, „Virtual Experiments“

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SCHOTTEL YOUR PROPULSION EXPERTS
02 Nozzle Optimization

>> Approach

Virtual Product Development:

Phase I: Suitable selection of nozzle geometries / parametrization
Phase II: Determine optimal nozzle design with computer simulations
Phase III: Verify optimized performance in model test
Phase VI: Check full scale performance
02 Nozzle Optimization

Nozzle >> Market-analysis >> Results

The diagram illustrates the optimization of nozzles across different market analyses, with results ranging from low-speed to high-speed conditions. It shows the performance of various nozzles in different speed ranges:

- Bollard Pull (0 kn)
- DP-Performance (0-2 kn)
- Towing (3-6 kn)
- Free Running (8-12 kn)
- Free Running (>12 kn)

The X-axis represents increasing shipspeed, while the Y-axis indicates the rank of the nozzles. The color gradient from low-speed to high-speed indicates the performance improvement of nozzles across different speeds.
Higher speed /Compromise optimized ducts

- moderate opening-angles, integrated cylindrical part for propeller, small diffusor
- L/D = 0.4 .. 0.45
- Propellerplane x/L = 0.55 .. 0.7
02 Nozzle Optimization

>> PreDesign Check - Model Based

- Performance check
  - Based on thrust load identity
  - Assessment of efficiency improvement

![Graph showing performance check results for Schottel Wag 19A mod and Predesign models.](image)
02 Nozzle Optimization
>> PHASE I

Virtual Product Development:

Phase I: Suitable selection of nozzle geometries / parametrization
Phase II: determine optimal nozzle design with computer simulations
Phase III: verify optimized performance in model test
Phase VI: check full scale performance
02 Nozzle Optimization

>> Parametrization

- Opening angle
- Radius Leading edge
- Inflow contour
- Diffusor geometry
02 Optimization-Workflow

>> Applied Tools

- Geometry Update
- CFD Calculation
- Optimizer

Optimization setup: Genetic algorithm
Input variables: 5 parameters
Design objective: Maximize BP- & FR-performance
02 Optimization-Workflow

>> Applied Tools

- Optimizer
  - DAKOTA

- Geometry-Update
  - dffMOD
  - geometry.stl

- Computational-Model
  - OpenFOAM

- Post-Processing
  - script (.sh)

- params.in
- results.out
02 Nozzle Optimization

>> Examined Designs

Examined Designs:

1. step:
- Inflow Optimization (150 designs)

2. step:
- Diffusor Optimization (79 designs)

Optimized Design:
- Maximized BP- & FR-performance
02 Nozzle Optimization

>> PHASE II

Virtual Product Development:

- **Market study**
- **Parameterization**

Phase I: Suitable selection of nozzle geometries / parametrization
Phase II: determine optimal nozzle design with computer simulations
Phase III: verify optimized performance in model test
Phase VI: check full scale performance
02 Nozzle Optimization
>> Modeltest

Modeltests with the optimized nozzle:
SVA-Potsdam

SRP 510 with optimized nozzle

Towing Tank
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>> Performance >> Open Water Test

**SDV45 „SCHOTTTEL VarioDuct“**
increased performance proofed in Open Water Tests

--- WAG19A-mod
--- SDV45

... identical bollard pull
and increased free sailing efficiency
03 Results
>> Performance >> Open Water Test

**SDV45 „SCHOTTEL VarioDuct“**
increased performance proofed in Open Water Tests

<table>
<thead>
<tr>
<th></th>
<th>Offshore Supply Vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Free-running-design, SRP430 FP, 1600kW, Dp=2.3m)</td>
</tr>
<tr>
<td>nozzle</td>
<td>WAG19A-mod</td>
</tr>
<tr>
<td>DP-thrust (1kn) [t]</td>
<td>47.1 (100%)</td>
</tr>
<tr>
<td>max. vessel speed [kn]</td>
<td>14.8 (100%)</td>
</tr>
<tr>
<td>power @ 14.8kn [kW]</td>
<td>1571 (100%)</td>
</tr>
</tbody>
</table>

... identical bollard pull

and increased free sailing efficiency
03 Results
>> Nozzle >> Performance

- **Bollard Pull (0 kn)**
- **DP - Performance (0-2 kn)**
- **Towing (3-6 kn)**
- **Free Running (8-12 kn)**
- **Free Running (>12 kn)**

**RANK**

**Low-Speed**

**High-Speed**

---

***initial nozzle***

***optimized nozzle***
03 Results
>> PHASE III

Virtual Product Development:

Phase I: Suitable selection of nozzle geometries / parametrization
Phase II: determine optimal nozzle design with computer simulations
Phase III: verify optimized performance in model test
Phase VI: check full scale performance
03 Results

>> SDV45

Bollard Pull Test: Harbout Tug - Geta Coast Guard

Speed Trial: Escort Tug - Dux
03 Results

>> PHASE IV

Virtual Product Development:

- Market study
- Parameterization

Phase I: Suitable selection of nozzle geometries / parametrization
Phase II: Determine optimal nozzle design with computer simulations
Phase III: Verify optimized performance in model test
Phase IV: Check full scale performance
03 Results
>> SDV45

SDV45 „SCHOTTEL VarioDuct“

...combines great bollard pull capacities
with excellent free sailing efficiency
at minimized installation space
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04 Integrated Anode Concept

>> Invention

The real life …

… a picture is worth a thousand words
04 Integrated Anode Concept
>> Invention

The invention ...

Zn anode  Al anode  MG anode

Integrated concept Zn/Al/Mg

... a picture is worth a thousand words
04 Integrated Anode Concept
>> Hydrodynamic Comparison >> OWC

Efficiency loss [%] (relative to blank nozzle)

max speed
transit

Anodelayout: best worst

SRP150 (1.1m)  SRP260 (1.75m)  SRP360 (2.2m)  SRP460 (2.7m)  SRP630 (3.2m)  integrated (blank)  blank nozzle
04 Integrated Anode Concept

>> Advantages

- less thruster weight

- **increased hydrodynamic efficiency:** higher speed, less fuel consumption

- **reduced risk** of anode damage

- minimum installation space

- **increased protection time:** up to 5 years and more